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B70 08026

SUBJECT: Effect of Lunar Surface Staytime and Overall Mission Duration on J-Mission Orbital Science Capability - Case 320

DATE: August 13, 1970

FROM: G. J. McPherson, Jr.

ABSTRACT

J-mission orbital science capability is being threatened by the consideration of longer surface staytimes and shorter overall mission durations. To minimize the effects, the Program is currently considering parallel surface and orbital science operations. A preliminary assessment is made of the orbital science capability offered by a number of mission options utilizing both series and parallel science operations.

The results indicate that as mission durations get shorter and surface staytimes get longer, parallel science offers increasingly more orbital science capability than a comparable series science mission. For a 66-hour surface stay, which is the likely candidate for the J-1 Mission, the following observations are made:

1. 15.3-day missions, which are currently marginal on SM cryo capability, would probably be limited to serial science operations because of the increased power consumption inherent in the parallel science options,

2. 13.3-day or less missions favor parallel operations regardless of RCS contamination,

3. 14.3-day missions are dependent upon the extent and effects of RCS contamination on the science instruments and could offer anywhere from 10 hours <u>less</u> to 40 hours <u>more</u> orbital science time.

Before a final judgement on series vs. parallel science operations can be made, a number of influences besides RCS contamination must be evaluated. Among the most significant are the revised ground tracks associated with parallel operations, the CMP's capability to perform the required tasks while solo, and the ground support network's capability to adequately support the concurrent operations.

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MEMORANDUM FOR FILE

A. INTRODUCTION

The reference Apollo J Mission is based upon a 54-hour surface stay, a subsequent (serial) 72-hour orbital science period, and a 15.3-day overall mission duration. A number of influences are threatening to reduce the orbital science capability significantly below the 72 hours offered by the reference mission. Primarily they are: 1) the Apollo 13 investigation and the resultant desire to reduce the overall mission duration to increase SM cryogenic margins, 2) the likelihood of extending the LM surface stay to ∿66 hours on Apollo 16 and possibly longer on later missions, and 3) the desire to provide sufficient SM cryogenic margins to support flexible launch options (T-24 ot T+24 hour liftoff capability).

To minimize the effect of a shortened mission duration and/or an extended surface staytime on orbital science capability, the Program has revived the concept of parallel science operations. This would call for initiation of the orbital science period shortly after LM touchdown. The concept had been previously ruled out because the SM RCS budget for orbital science was dependent upon unused LM rescue propellant; also, the reference mission provided for an adequate post-rendezvous orbital science period (72 hours). Additionally, there was concern over potential science instrument contamination by SM RCS +X translation maneuvers (such as required for LOPC-1*) with the scientific instrument module door removed.

The impending reduction in orbital science time has led to a recent reevaluation of RCS capability ** that indicates support of parallel science operations is now feasible. This leaves instrument contamination *** as the primary unknown in weighing the benefits and penalties associated with parallel science operations.

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* Lunar orbit plane change for rendezvous.

** MSC Memorandum 70-FM-74-169, SM RCS Propellant Usage, Apollo 16 Mission, July 1, 1970.

*** Contamination sources other than the RCS jets (such as water and urine dumps) are not treated within this study since they are present in both the series and parallel science options.

It is the intent of this study to: 1) develop representative mission and orbital science timelines for select mission options, 2) make a preliminary assessment of the orbital science capability of each, and 3) identify some of the pertinent factors requiring further attention before a final decision on series vs. parallel science can be made.

B. APPROACH

Three basic surface staytimes (54, 66, and 72 hours) are under consideration by the Program and are used in development of the mission options to be assessed herein. Mission and orbital science timelines are developed using the three surface staytimes for the serial science options. Only the 66 and 72-hour staytimes are used for the parallel science timelines since the 54-hour staytime no longer appears to be a real candidate. The serial science options use a 15.3-day mission duration;* the parallel science options assume a 14.3-day maximum mission duration that retains a significant orbital science capability while increasing consumable margins.

Although the timelines developed are limited to the options described above, other mission options are derived from them. The derivations result in data for 13.3 and 14.3-day serial science missions and 13.3-day parallel science missions. Additionally, data for a 54-hour surface stay are extrapolated for the parallel science option.

C. DISCUSSION

1. Mission Timelines

Figure 1 consists of overall mission timelines for the five basic mission options assessed. The mission event times (TLI, LOI, DOI, etc.) are based on the reference J Mission. The 14.3-day parallel science missions assume a TEI time 24 hours earlier than that of the 15.3-day reference mission. The construction of overall mission timelines was necessary to acquire insight into the crew wake/sleep cycles and to see how they could be scheduled around milestone events having established occurrence times. The mission timelines also provided the mechanism for establishing a relationship between the surface EVA timelines ** and the orbital science activities.

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* This study assumes that the SM cryo system is not capable of supporting a 15.3-day parallel science mission.

** Memorandum for File, Operational Constraints for J-mission Traverse Planning, P.Benjamin, January 7, 1970. Memorandum for File, Fourth Lunar Surface Reference Mission Plan Meeting, P. Benjamin, and J. Llewellyn, April 3, 1970.

2. Orbital Science Timelines

Apollo 16 orbital science timelines based on the mission timelines discussed above are shown in Figure 2. It should be noted that the five timelines are constructed against a common ground elapsed time (GET).

The significant assumptions and groundrules used in construction of the orbital science timelines are contained in Table 1. While some are not necessarily valid for actual mission planning, they simplified construction of the timelines without unduly favoring a particular option. The instrument operate times lost during LCRU operation,* plane changes, and rendezvous/docking activities are shown as shadowed areas for the parallel science options.

3. Capability Assessment

The tabulated data of Table 2 indicate the instrument operate times for each of the five orbital science timelines of Figure 2 as well as for the derived 14.3-day serial science missions. The data for the 14.3-day serial science missions were determined based upon performing TEI 24 hours earlier than shown on Options A, B and C.

The instrument operate times of Table 2 are segregated into three categories relevant to comparison of the options:

a. Operation under proper conditions ----

   Operation prior to LOPC-1; no boom-mounted instruments in a camera field-of-view during camera operation; and boom-mounted instruments fully extended during their operation,

b. Operation in degraded configuration ----

   Operation with boom-mounted instruments in a camera field-of-view or boom-mounted instruments not fully extended,

c. Operation after LOPC-1 (potential contamination)** ---- operation subsequent to firing the RCS engines for the LOPC-1 maneuver.

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* LCRU and CSM FM downlink shared a common frequency at the time of this study. The effects of an LCRU frequency change will be evaluated as part of a subsequent study.

** The data acquired subsequent to LOPC-1 can fall into both categories b and c. Footnotes are provided in Table 2 where applicable.

Although Table 2 provides a detailed breakdown of the instrument operate times based on the writer's orbital science timelines, the times could vary somewhat when based on another set of timelines. Therefore, Table 2 should not be construed as "the" operate times for the particular options but should be used as a baseline from which to perform tradeoffs between the various instrument operate times when considering modifications to the writer's timelines. A less detailed and more illustrative indicator of the orbital science capability of each mission option is included as Figure 3.

Figure 3 indicates the orbital science time available from various mission options and provides a measure of how much of the orbital science periods would be jeopardized by potential RCS contamination. The parallel science durations have been reduced to reflect the orbital science time lost due to CSM/LCRU frequency conflicts and CSM execution of plane change and rendezvous/docking activities.

By assuming the two extremes of instrument contamination, the orbital science capability of the various options could be assessed as in Figure 4. It can be seen from Figure 4 that for the anticipated 66-hour surface stay that:

1. a 15.3-day mission would probably be limited to serial science (based on assumed cryo capabilities),

2. a 13.3-day (or less) mission favors parallel science,

3. a 14.3-day mission is dependent upon the extent of science instrument contamination and its effect on instrument performance.

Because the Program currently seems to favor a shorter mission duration, Apollo 16 does not seem a likely candidate for a 15.3-day mission. Since the 14.3-day mission options (both series and parallel) appear to display positive cryo redline margins for the T-0 and T+24 hour launch cases*, and could have a positive redline margin for the T-24 hour launch case,** it would seem the likely one for consideration.

It can be seen from Table 2 and Figure 3 that dependent upon the amount of instrument contamination and its effect on data quality, the 14.3-day, 66-hour surface stay, parallel science option potentially offers between 10 hours less and >40 hours more instrument operate time than the corresponding serial option. If RCS contamination remains the primary concern and

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* Based on the writer's calculations.

** By either late cryo topoff or reduced power levels during TLC.

its extent and effects are not known prior to decision time, it would seem the wiser investment to implement the parallel option based on the potentiality of 40 hours additional science time and the improbability of total contamination of all instruments.

For the J-1 mission, where some consideration has been given to implementing the serial option and intentionally exposing the instruments to RCS contamination (near the end of the orbital science period) for purposes of evaluating its effects on data quality, the parallel option would seem to offer a clear advantage. Under these conditions, the parallel option would offer essentially the same amount of uncontaminated data as the serial option and also the 40 hours of additional post-LOPC-1 science time.

It should be noted, however, that there are numerous additional factors besides contamination that must be considered before a final determination can be made of which science mode offers the greater orbital science capability. Some are listed here for the readers' consideration.

1. ability of the ground support elements to accommodate parallel science operations,

2. ability of the CMP to perform the numerous orbital science and CSM tasks while in the solo mode,

3. effect of the revised orbital ground tracks * inherent in the parallel options (mission dependent),

4. effect of the LM lifeboat option if implemented,

5. effect of CSM FM downlink data loss on Pan and Mapping Camera operation during LCRU operations,

6. advantages of separate sleep periods for the CMP during the surface staytime,

7. effect of subsatellite ejection and checkout on the various options,

8. impact of different instrument configurations on later J Missions.

* Seems to be of lesser concern at this time than the potential RCS contamination, but none-the-less will be pertinent to the series vs. parallel decision.

D. CONCLUSIONS

Parallel science missions offer significantly more orbital science time than comparable series science missions and become increasingly attractive as mission durations get shorter and surface staytimes get longer. However, the net science return from the parallel options must be evaluated in more detail to determine the effects of potential instrument contamination and different orbital ground track coverage.

For the anticipated 66-hour surface stay on Apollo 16:

1. mission durations of less than 14 days favor parallel operations regardless of instrument contamination,

2. mission durations of more than 14 days favor serial operations,

3. 14-day parallel science missions offer from 10 hours <u>less</u> to 40 hours <u>more</u> science time and, hence, favor parallel operations unless near total contamination of all instruments occurs.

Detailed parallel science timelines and in-depth assessments of all influences, including contamination, are necessary to make a final judgement on the relative merits of series and parallel science.

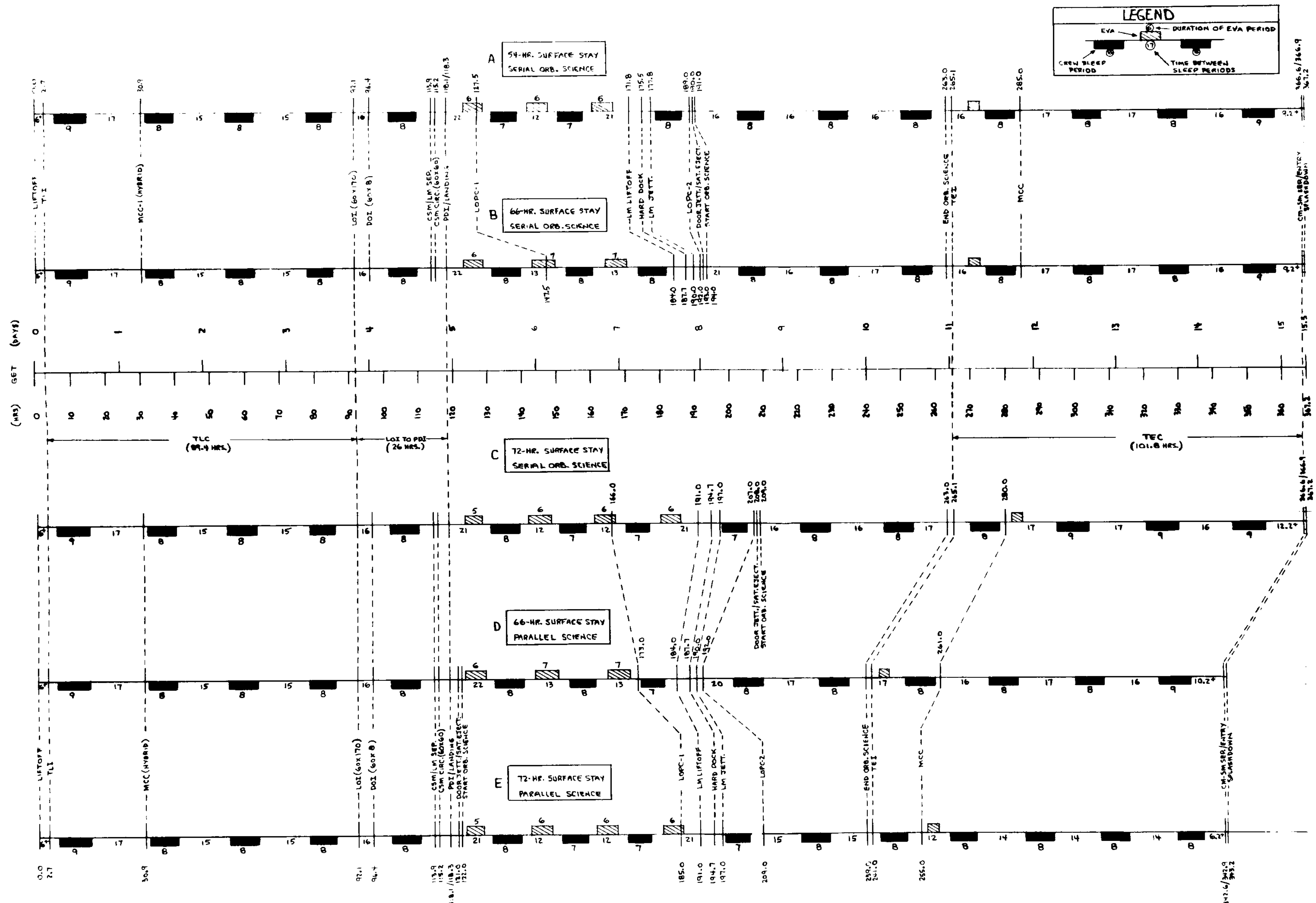
2032-GJM-meh

G. J. McPherson, Jr.

Attachments

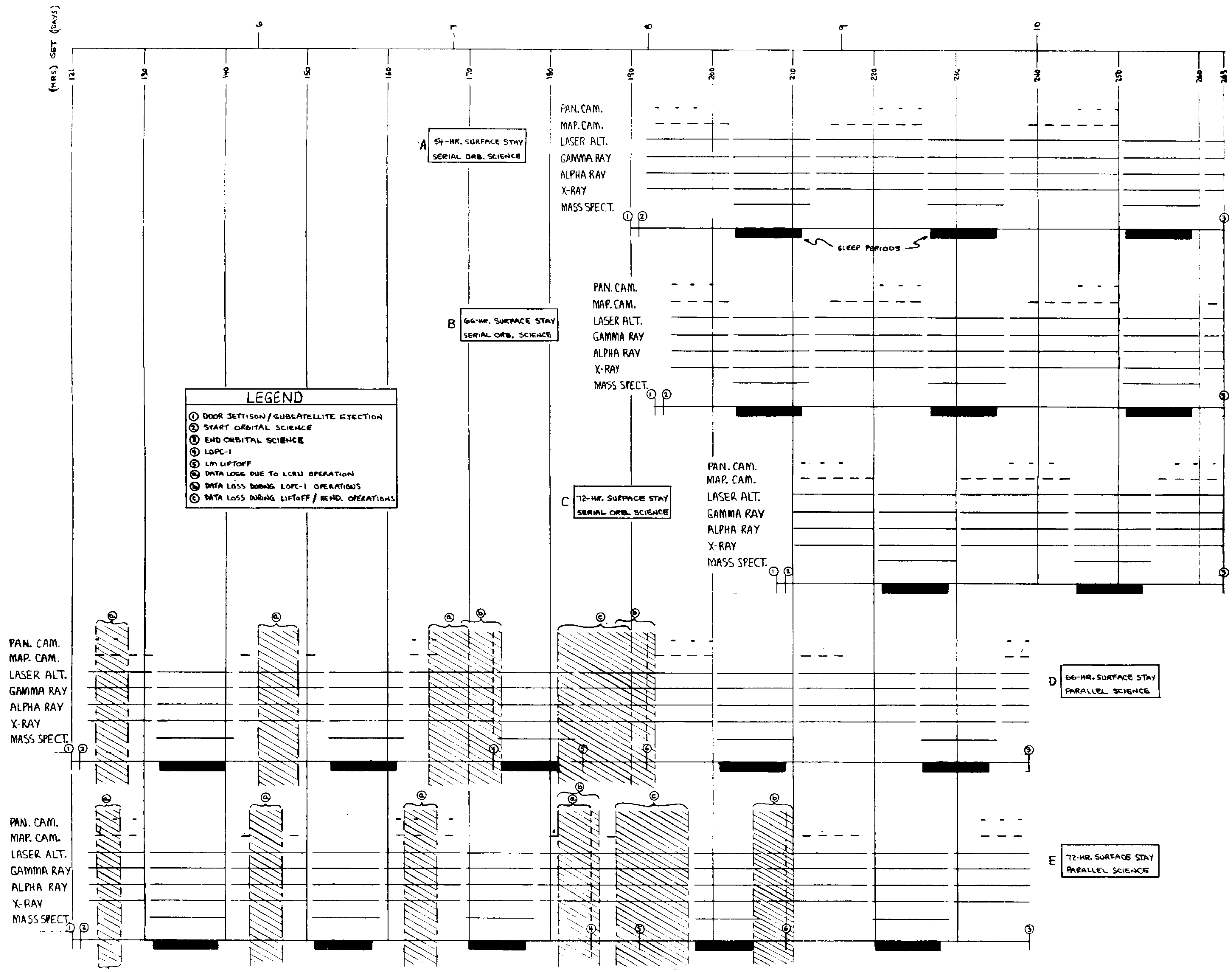
Figures 1 - 4

Tables 1 and 2



J MISSION TIMELINES
FIGURE 1

G. T. NICKERSON JR. BELLCOMM 6-12-70



ORBITAL SCIENCE TIMELINES
FIGURE 2

G. J. McPHERSON JR. BELLCOMM 6-15-70

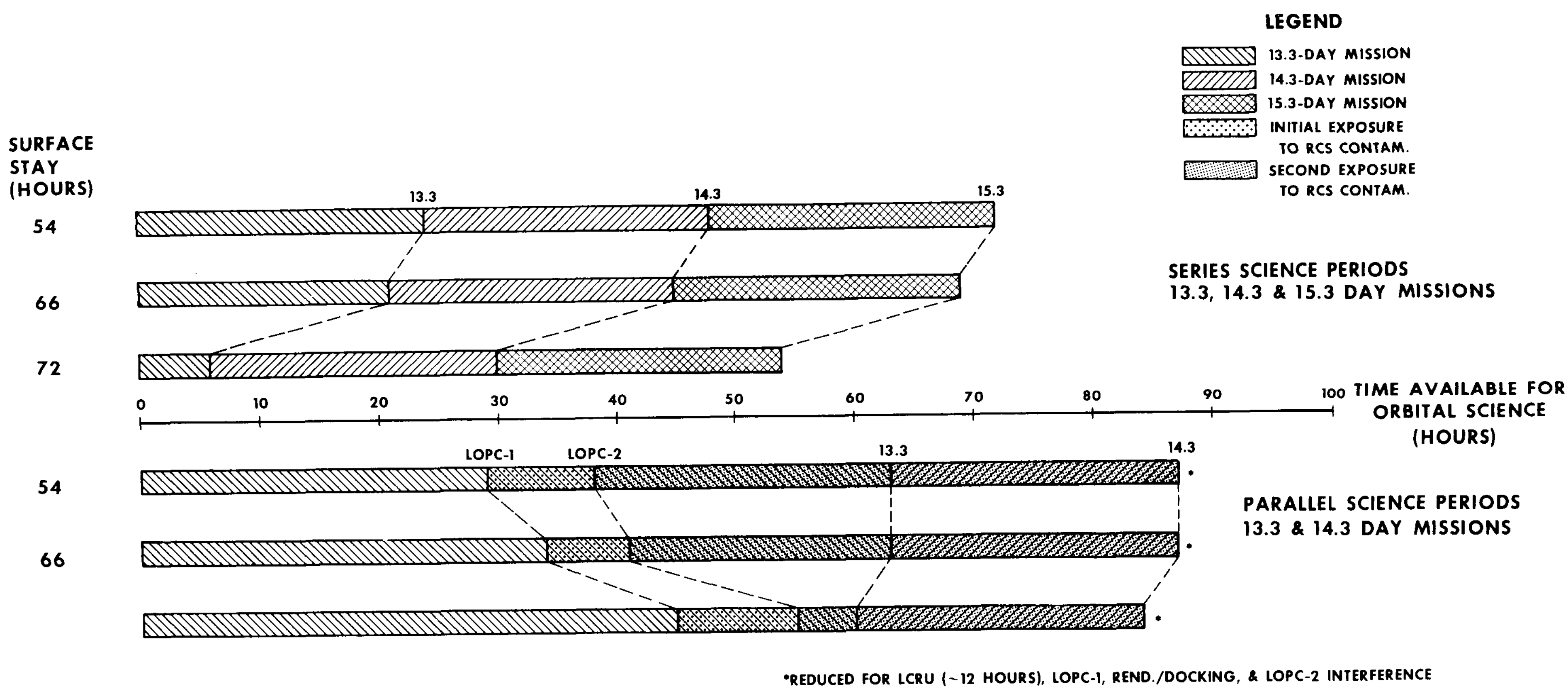


FIGURE 3 - ORBITAL SCIENCE OPTIONS AND DURATIONS

		MISSION DURATION (DAYS)					
		13.3		14.3		15.3	
		NO CONTAMINATION	TOTAL CONTAMINATION	NO CONTAMINATION	TOTAL CONTAMINATION	NO CONTAMINATION	TOTAL CONTAMINATION
SURFACE STAY (HRS)	54	P	P	P	S	S*	S
	66	P	P	P	S	S*	S
	72	P	P	P	P	S*	S

P PARALLEL SCIENCE APPEARS TO OFFER THE GREATER CAPABILITY

S SERIES SCIENCE APPEARS TO OFFER THE GREATER CAPABILITY.

* ASSUMES CRYO CAPABILITY WOULD NOT SUPPORT A 15.3-DAY PARALLEL MISSION BUT COULD SUPPORT A 15.3-DAY SERIES MISSION.

FIGURE 4 - ORBITAL SCIENCE CAPABILITY ASSESSMENT

TABLE 1

ORBITAL SCIENCE TIMELINE ASSUMPTIONS/GROUNDRULES

GROUNDRULES

- MAXIMIZE INSTRUMENT OPERATE TIMES
- NEGLECT BOOM EXTEND/RETRACT TIMES
- USE SIMULTANEOUS CREW SLEEP PERIODS
- NEGLECT SCHEDULING METRIC CAMERA OPERATION ON DARK SIDE FOR CORRELATION OF LASER DATA

ASSUMPTIONS

- NO DATA LOSS ATTRIBUTABLE TO DATA SYSTEM
- CSM X-AXIS REVERSALS INTERRUPT DATA ACQUISITION FOR 30 MINUTES PER 24-HOUR PERIOD
- DEEP SPACE CALIBRATIONS CAN BE ACCOMPLISHED WITHIN THE 30 MINUTES ALLOCATED FOR X-AXIS REVERSALS
- NO DATA LOSS DURING IMU ALIGNMENTS
- BOOMS RETRACTED DURING ALL PAN CAMERA OPERATIONS
- BOOMS RETRACTED DURING FIVE METRIC CAMERA PHOTO PASSES
- TOTAL CSM FM DATA LOSS DURING LCRU OPERATION
- LOPC-1 CAN BE PERFORMED AS LATE AS SIX HOURS PRIOR TO LM LIFTOFF
- NO CSM EXPERIMENTATION FOR FOUR HOURS PRIOR TO, AND ONE HOUR AFTER, LOPC-1
- NO CSM EXPERIMENTATION FOR THREE HOURS PRIOR TO, AND SIX HOURS AFTER, LM LIFTOFF
- ALL INSTRUMENTS ARE SUSCEPTIBLE TO CONTAMINATION BY RCS EXHAUST DURING LOPC-1, RENDEZVOUS/DOCKING, AND LOPC-2 WITH THE SIM DOOR REMOVED
- OTHER CONTAMINATION SOURCES ARE NOT OF THE SAME LEVEL OF CONCERN AS RCS CONTAMINATION
- 14.3 DAY MISSION DURATIONS WOULD PROVIDE SATISFACTORY CONSUMABLE MARGINS
- PHOTOGRAPHIC DATA CAN BE ACQUIRED DURING LCRU DATA BLACKOUT

TABLE 2 - INSTRUMENT OPERATE TIMES

		INSTRUMENT OPERATE TIMES (HOURS)							
		OPERATION UNDER PROPER CONDITIONS		OPERATION IN DEGRADED CONFIGURATION		OPERATION AFTER LOPC-1 (POTENTIAL CONTAMINATION)		TOTAL INSTRUMENT OPERATE TIMES	
	MISSION DURATION	14.3	15.3	14.3	15.3	14.3	15.3	14.3	15.3
A 54-Hr. Surface Stay Serial Orb. Science	PAN. CAM.	2.75	2.75			—	—	2.75	2.75
	MAP. CAM.	7.0	7.0	7.0*	10.0*	—	—	14.0	17.0
	LASER ALT.	45.0	68.0			—	—	45.0	68.0
	GAMMA RAY	38.0	61.0	7.0**	7.0**	—	—	45.0	68.0
	X-RAY	45.0	68.0	—		—	—	45.0	68.0
	ALPHA PART.	45.0	68.0	—		—	—	45.0	68.0
	MASS SPECT.	19.0	28.5	—		—	—	19.0	28.5
B 66-Hr. Surface Stay Serial Orb. Science	PAN. CAM.	2.75	2.75	—	—	—	—	2.75	2.75
	MAP. CAM.	7.0	7.0	6.0*	10.0*	—	—	13.0	17.0
	LASER ALT.	41	64.0	—	—	—	—	41.0	64.0
	GAMMA RAY	34	57.0	7.0**	7.0**	—	—	41.0	64.0
	X-RAY	41	64.0	—	—	—	—	41.0	64.0
	ALPHA PART.	41	64.0	—	—	—	—	41.0	64.0
	MASS SPECT.	19	28.5	—	—	—	—	19.0	28.5
C 72-Hr. Surface Stay Serial Orb. Science	PAN. CAM.	2.75	2.75	—	—	—	—	2.75	2.75
	MAP. CAM.	4.0	7.0	8.0*	9.0*	—	—	12.0	16.0
	LASER ALT.	28.0	51.0	—	—	—	—	28.0	51.0
	GAMMA RAY	21.0	44.0	7.0**	7.0**	—	—	28.0	51.0
	X-RAY	28.0	51.0	—	—	—	—	28.0	51.0
	ALPHA PART.	28.0	51.0	—	—	—	—	28.0	51.0
	MASS SPECT.	9.5	19.0	—	—	—	—	9.5	19.0
D 66-Hr. Surface Stay Parallel Science	PAN. CAM.	1.33[1]	—	—	—	1.42	—	2.75	—
	MAP. CAM.	3.0[2]	—	5.0*	—	9.0[3]	—	17.0	—
	LASER ALT.	31.0	—	—	—	51.0	—	82.0	—
	GAMMA RAY	28.0	—	3.0**	—	51.0[3]	—	82.0	—
	X-RAY	31.0	—	—	—	51.0	—	82.0	—
	ALPHA PART.	31.0	—	—	—	51.0	—	82.0	—
	MASS SPECT.	19.0	—	—	—	26.0	—	45.0	—
E 72-Hr. Surface Stay Parallel Science	PAN. CAM.	2.0[1]	—	—	—	0.75	—	2.75	—
	MAP. CAM.	4.66[2]	—	4.34*	—	8.0[3]	—	17.0	—
	LASER ALT.	44.0	—	—	—	38.0	—	82.0	—
	GAMMA RAY	40.0	—	4.66**	—	37.34[3]	—	82.0	—
	X-RAY	44.0	—	—	—	38.0	—	82.0	—
	ALPHA PART.	44.0	—	—	—	38.0	—	82.0	—
	MASS SPECT.	26.5	—	—	—	17.0	—	43.5	—

*Gamma Ray in Field-of-View
**Boom not Fully Extended

1 Includes 1.0 Hr. of No TM Data
2 Includes 1.66 Hrs. of No TM Data
3 Includes some operation in degraded configuration

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